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(54) **VOLTAGE GENERATING APPARATUS AND METHODS**

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H03F 3/04 (2006.01)

(52) **U.S. Cl.** **330/297**

(58) **Field of Classification Search** **330/51,**
330/127, 207 A, 251, 297

See application file for complete search history.

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7,061,327 B2 6/2006 Doy
7,382,195 B2 * 6/2008 Chen et al. 330/297
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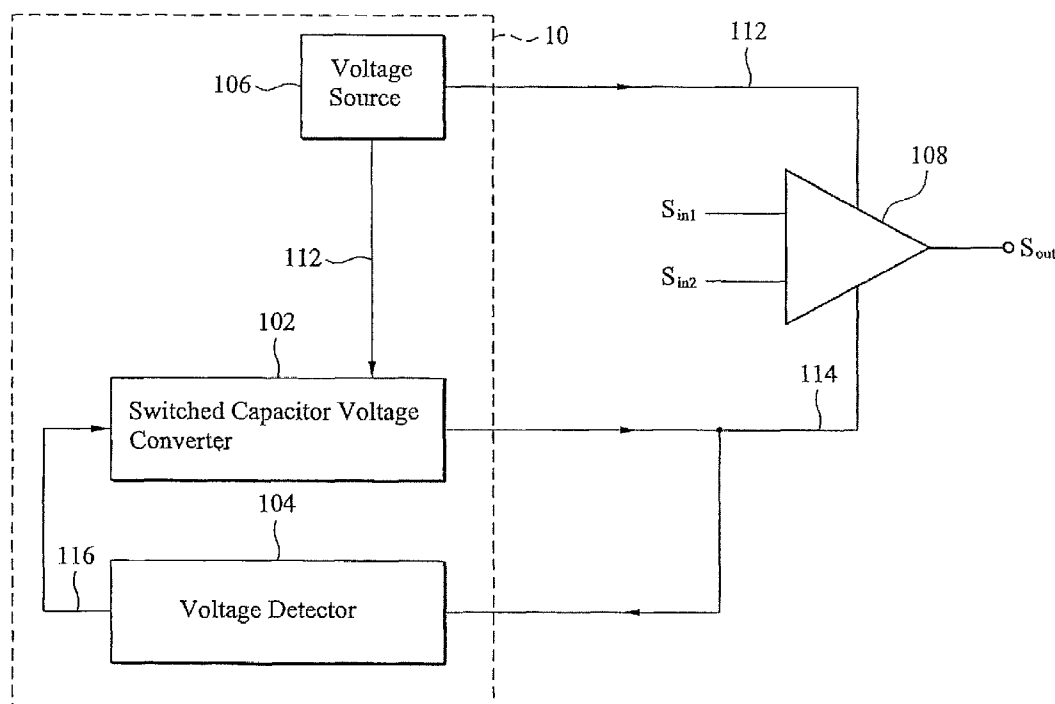
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(57) **ABSTRACT**

The invention provides a voltage generating apparatus for powering at least one amplifier. The voltage generating apparatus comprises a voltage source, a switched capacitor voltage converter and a voltage detector. The voltage source supplies a first voltage to a positive voltage input terminal of the at least one amplifier. The first voltage is a positive DC voltage. The switched capacitor voltage converter is coupled to the voltage source for outputting an output voltage to a negative voltage input terminal of the at least one amplifier according to the first voltage and a predetermined voltage. The output voltage is a negative DC voltage. The voltage detector is coupled to the switched capacitor voltage converter for determining a switching frequency corresponding to the predetermined voltage according to the output voltage. The switched capacitor voltage converter increases the output voltage when the switching frequency is decreased and decreases the output voltage when the switching frequency is increased.

14 Claims, 5 Drawing Sheets



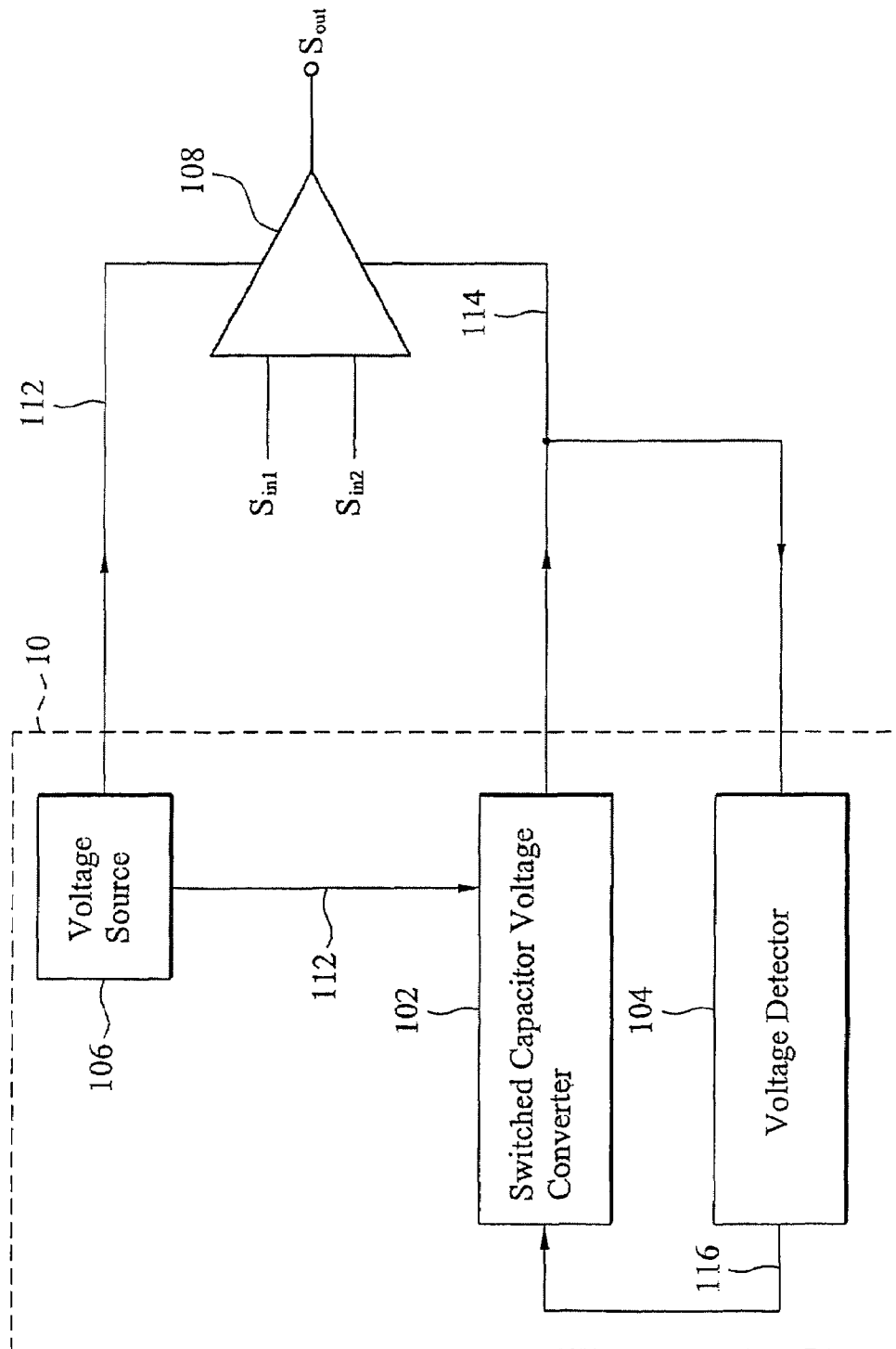


FIG. 1

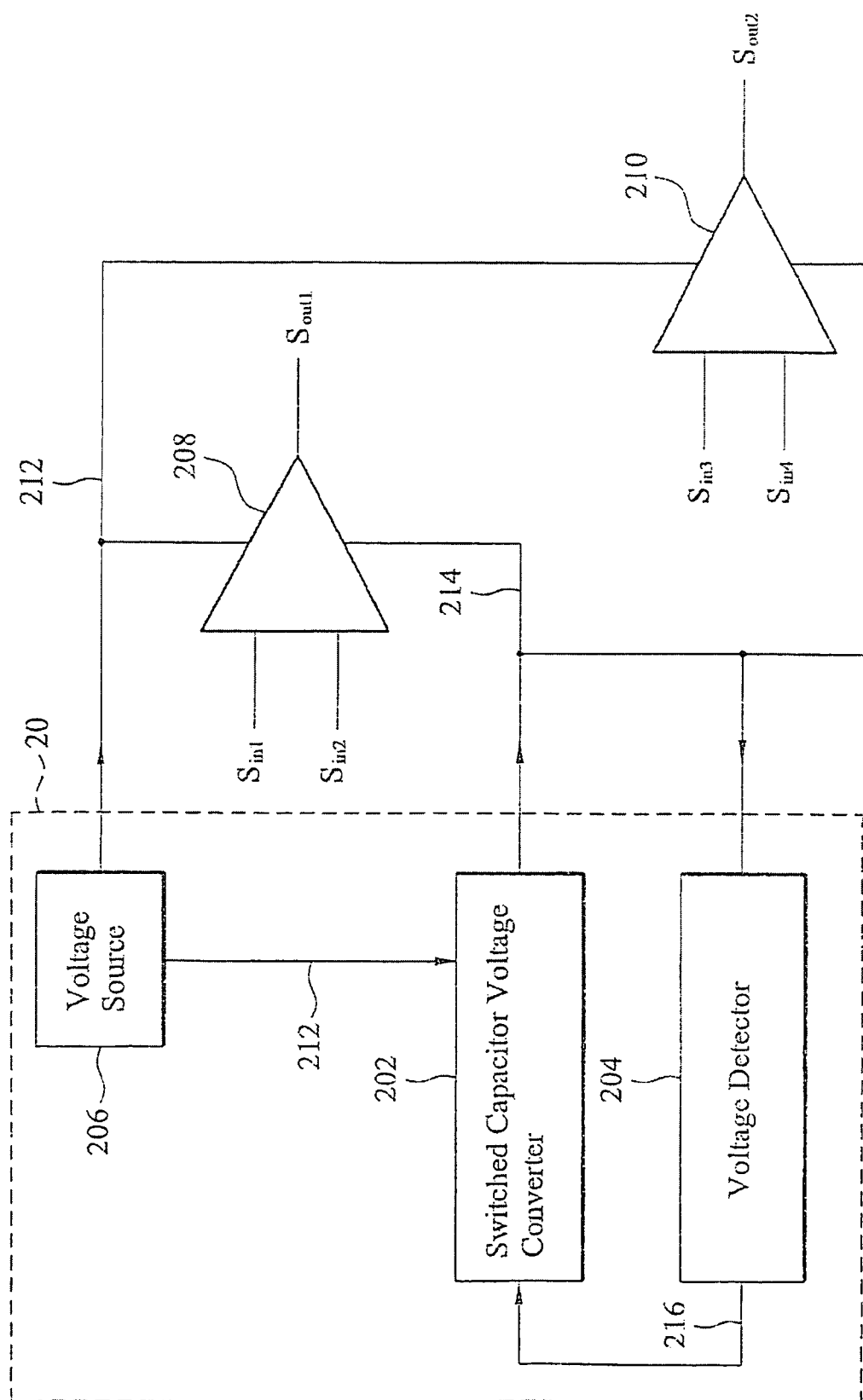


FIG. 2

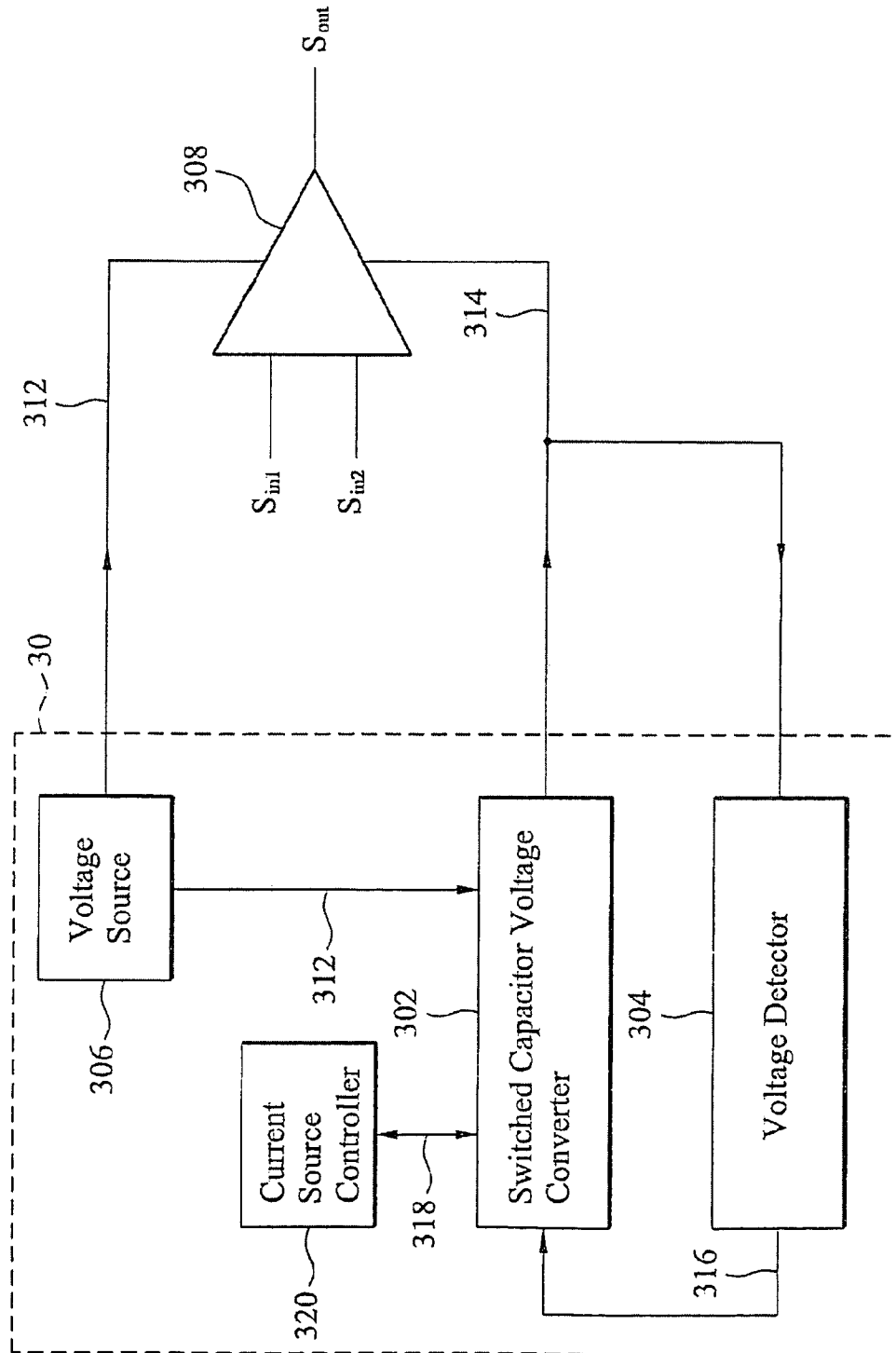


FIG. 3

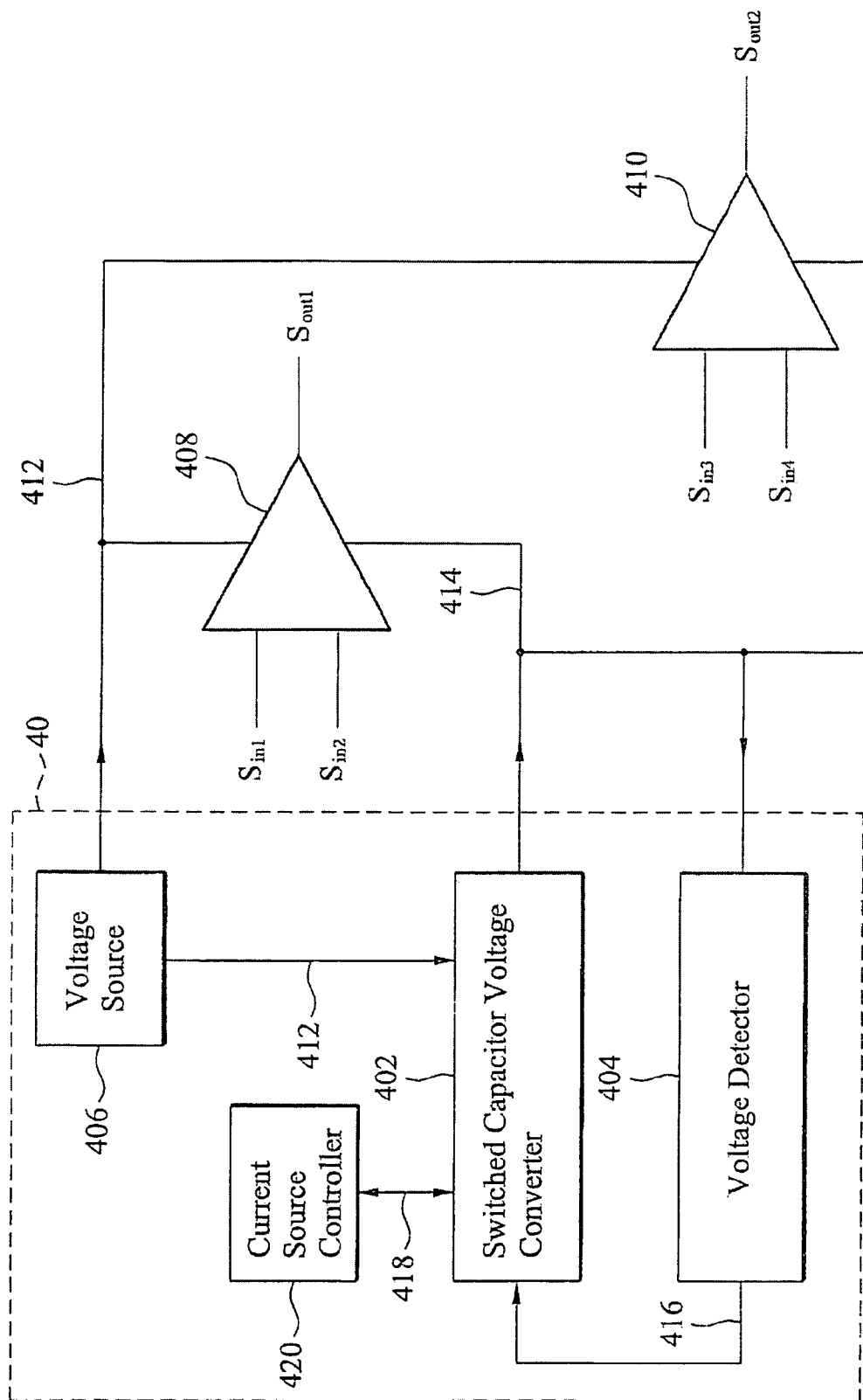


FIG. 4

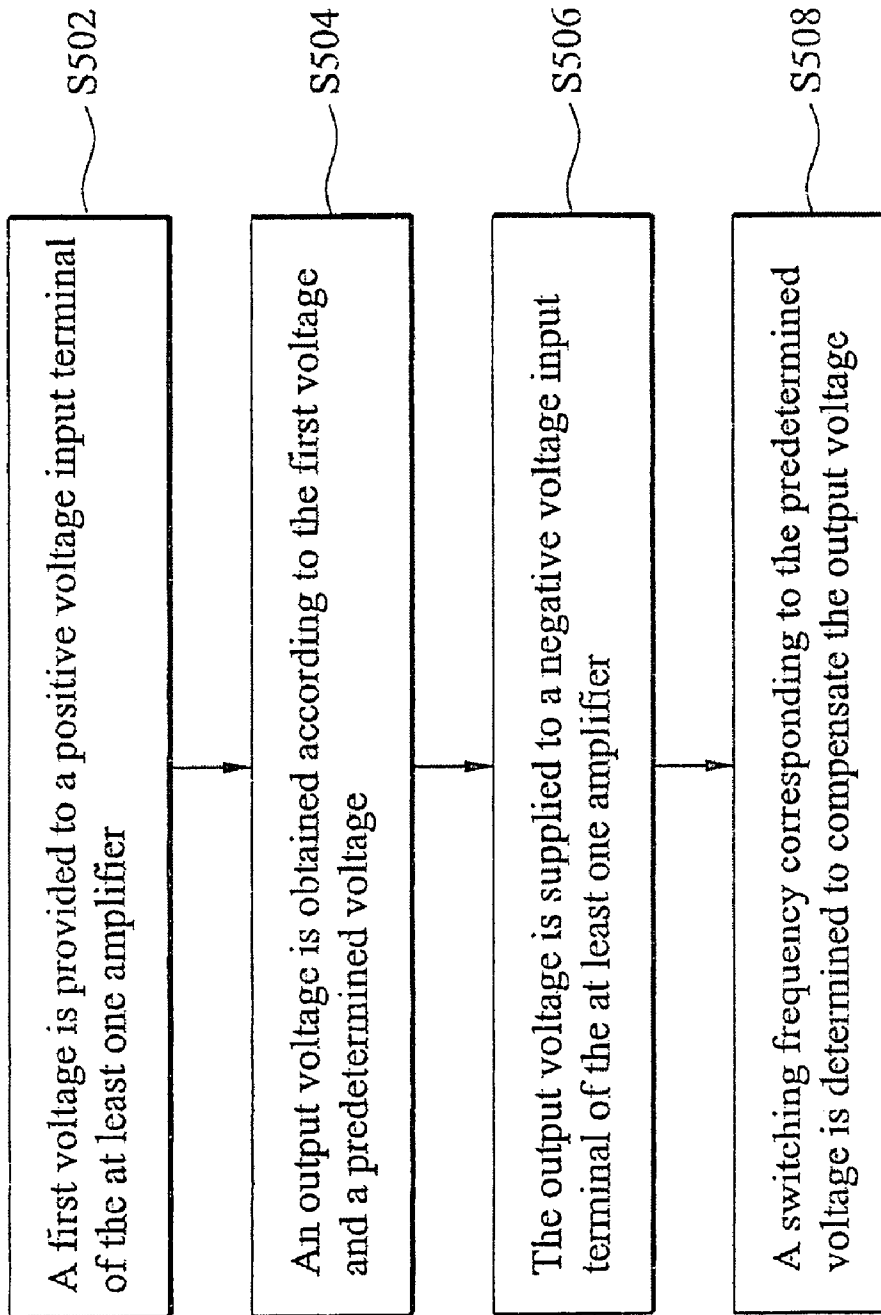


FIG. 5

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VOLTAGE GENERATING APPARATUS AND METHODS

BACKGROUND OF THE INVENTION CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/969,872, filed Sep. 4, 2007, the entirety of which is/are incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to power supply devices, and more particularly to a voltage generating apparatus and methods for reducing power dissipation and allowing voltage compensation for driving amplifiers.

2. Description of the Related Art

Amplifiers, such as operational amplifiers, are well known in the field of electronic circuits for providing amplification of input signals to drive a variety of electrical loads such as audio speakers. For example, U.S. Pat. No. 7,061,327 illustrates a headphone driver amplifier operative from a single voltage supply, thereby driving headphone speakers. Also, an operational amplifier driven by a charge pump with a single supply voltage is disclosed in U.S. Pat. No. 5,289,137.

According to the prior art, an operational amplifier is operative in an operating range to properly drive electrical loads over the operating range. For example, it is necessary for an operational amplifier to provide a sufficiently broad range that spans from a specific negative voltage (such as -5 volts) up to a specific positive voltage (such as +5 volts) so as to assure the full amplification of input signals. However, in prior art systems, ripple effects, transients, or other disruptive occurrences may instantaneously produce voltage shot or spike of the specific negative voltage, thereby affecting the lower limit of the operating range. Consequently, a magnitude of amplification of an input signal from the operational amplifier accordingly deteriorates. This is particularly a problem for an operational amplifier powered by dual voltage signals, such as -5 and +5 volts, providing full amplification of input signals.

Some conventional methods are provided for increasing the operating range of the amplifier. As the operating range of the amplifier increases, power dissipation is accordingly increased, thus decreasing the efficiency of the system.

In view of the aforementioned, a need exists to provide a voltage generating apparatus that can derive a stable negative voltage in response to input signals. In addition, there is a need for a voltage generating apparatus that is capable of reducing fluctuations in the negative voltage and providing a stable desired output voltage level based on user needs, thereby making the generation of the negative voltage more reliable and predictable.

BRIEF SUMMARY OF THE INVENTION

In one aspect, the invention provides a voltage generating apparatus for powering an amplifier. The voltage generating apparatus comprises a voltage source, a switched capacitor voltage converter and a voltage detector. The voltage source supplies a first voltage to a positive voltage input terminal of the at least one amplifier. The first voltage is a positive DC voltage. The switched capacitor voltage converter is coupled to the voltage source for outputting an output voltage to a negative voltage input terminal of the at least one amplifier according to the first voltage and a predetermined voltage. The output voltage is a negative DC voltage. The voltage detector is coupled to the switched capacitor voltage converter for determining a switching frequency corresponding

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to the predetermined voltage according to the output voltage. The switched capacitor voltage converter increases the output voltage when the switching frequency is decreased and decreases the output voltage when the switching frequency is increased.

In a further aspect of the invention, a voltage generating method is provided for driving at least one amplifier. The voltage generating method comprises the steps of providing a first voltage to a positive voltage input terminal of the at least one amplifier, wherein the first voltage is a positive DC voltage. Next, an output voltage is generated according to the first voltage and a predetermined voltage, wherein the output voltage is a negative DC voltage. Also, the output voltage is supplied to a negative voltage input terminal of the at least one amplifier and a switching frequency corresponding to the predetermined voltage according to the output voltage is determined. The output voltage is increased when the switching frequency is decreased and is decreased when the switching frequency is increased.

A detailed description is given in the following embodiments with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

FIG. 1 is a block diagram of a voltage generating apparatus for driving an amplifier in accordance with one embodiment of the invention;

FIG. 2 is a block diagram of a voltage generating apparatus for driving two amplifiers in accordance with another embodiment of the invention;

FIG. 3 is a block diagram of a voltage generating apparatus for driving an amplifier in accordance with still another embodiment of the invention;

FIG. 4 is a block diagram of a voltage generating apparatus for driving two amplifiers in accordance with still another embodiment of the invention; and

FIG. 5 is a flowchart of a voltage generating method for driving at least one amplifier in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

The following description is of the best-contemplated mode of carrying out the invention. This description is made for the purpose of illustrating the general principles of the invention and should not be taken in a limiting sense. The scope of the invention is best determined by reference to the appended claims.

FIG. 1 is a block diagram of a voltage generating apparatus 10 for driving an amplifier 108 in accordance with one embodiment of the invention. The voltage generating apparatus 10 comprises a voltage source 106, a switched capacitor voltage converter 102 and a voltage detector 104. The voltage source 106 is provided for generating a first voltage 112, where the first voltage 112 is a positive DC voltage outputted to a positive voltage input terminal of the amplifier 108. The switched capacitor voltage converter 102 coupled to the voltage source 106 receives the first voltage 112 and delivers an output voltage 114 to a negative voltage input terminal of the amplifier 108, where the output voltage is a negative DC voltage. In other words, the amplifier 108 is connected to an upper supply rail of the first voltage 112 and a lower supply rail of the output voltage 114. The voltage detector 104 is coupled to the switched capacitor voltage converter 102 for determining a switching frequency 116 corresponding to a predetermined voltage (not shown) according to the output voltage 114. The operation of the voltage detector 104 is

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described below in more detail. In the illustrated embodiment, the switched capacitor voltage converter **102** increases the output voltage **114** when the switching frequency is decreased. Further, the output voltage **114** is decreased when the switching frequency is increased

As shown in FIG. 1, the first voltage **112** and the output voltage **114** are provided for powering the amplifier **108**. The amplifier **108** has a pair of signal input terminals to receive and amplify signals S_{in1} and S_{in2} , such as audio signals for speakers, so that a full swing of an amplified signal S_{out} obtained therefrom can be achieved. The amplifier **108** used in this embodiment is preferably an operational amplifier, such as a dual input bipolar operational amplifier. It is noted that signal amplification from the amplifier **108** of one signal can also be applicable.

According to this embodiment, the voltage detector **104** is provided for compensating the variation of the output voltage **114**, thereby maintaining the lower limit of the operating range of the amplifier **108**. When the aforesaid variation is detected by the voltage detector **104**, the switching frequency **116** is then determined, thereby generating the predetermined voltage from the switched capacitor voltage converter **102**. Accordingly, the output voltage **114** is compensated by the switching frequency **116**. For example, when the output voltage **114** is increased, the switching frequency **116** is attenuated to control the charge time of a predetermined capacitor (not shown) in the switched capacitor voltage converter **102**, thereby reducing the predetermined voltage to compensate for the output voltage **114**. Moreover, the switching frequency **116** is decreased to raise the predetermined voltage of the switched capacitor voltage converter **102**, thereby compensating for the voltage drop of the output voltage **114**.

In operation, the switched capacitor voltage converter **102** and the voltage detector **104** operate so the output voltage **114** is set as function of the first voltage **112** and the predetermined voltage corresponding to the switching frequency **116**, described as follow:

$$V_{out} = -V_{in} + V_c,$$

where “ V_{out} ” indicates the output voltage **114** derived from the switched capacitor voltage converter **102** according to FIG. 1, “ V_{in} ” indicates the first voltage **112** generated from the voltage source **106**, and “ V_c ” indicates the predetermined voltage corresponding to the switching frequency **116** from the voltage detector **104**.

FIG. 2 is a block diagram of a voltage generating apparatus **20** for driving two amplifiers **208** and **210** in accordance with another embodiment of the invention. In this embodiment, the voltage generating apparatus **20** comprises a voltage source **206**, a switched capacitor voltage converter **202** and a voltage detector **204**. Note that the operations of the voltage source **206**, the switched capacitor voltage converter **202** and the voltage detector **204** are substantially similar to corresponding units of FIG. 1, and hence, further description thereof is omitted.

As shown in FIG. 2, the voltage generating apparatus **20** provides a first voltage **212** and an output voltage **214** for respectively operating as upper supply rails and lower supply rails of two amplifiers **208** and **210**. In order for the amplifiers **208** and **210** to provide full amplification of signals S_{in1} , S_{in2} , S_{in3} and S_{in4} , an adequate operating range of driving voltage supplied from the first voltage **212** and the output voltage **214** is required. In this case, the switched capacitor voltage converter **202** is used to stabilize the voltage level of the output voltage **214**. Therefore, as the output voltage **214** varies, the switched capacitor voltage converter **202** adjusts the value of the first voltage **212** according to a predetermined voltage in response to a switching frequency **216** from the voltage detector **204**, so as to maintain a stable output voltage **214**.

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Furthermore, when the negative magnitude of an input signal (such as signal S_{in1} in FIG. 1) increases (or decreases), the lower limit of the operating range to power the amplifier (such as the amplifier **108** in FIG. 1) also needs to be correspondingly increased (or decreased). Thus, an extra control to assure full amplification of the input signal is required.

FIG. 3 is a block diagram of a voltage generating apparatus **30** for driving an amplifier **308** in accordance with still another embodiment of the invention. Referring to FIG. 3, a current source controller **320** is further provided for supplying an extra voltage **318** to a switched capacitor voltage converter **302** so as to directly adjust an output voltage **314**. The extra voltage **318** is determined by modulating a current flowing in or flowing from the switched capacitor voltage converter **302**. Therefore, when the negative magnitude of the input signals S_{in1} and S_{in2} is changed, full amplification of the variable input signals S_{in1} and S_{in2} is accomplished. Note that structures and operations in the voltage generating apparatus **30** are similar to those of FIG. 1, and hence, further description thereof is omitted for brevity.

FIG. 4 is a block diagram of a voltage generating apparatus **40** for driving two amplifiers **408** and **410** in accordance with still another embodiment of the invention. In this embodiment, as described above, the voltage generating apparatus **40** provides two voltages **412** and **414** to drive amplifiers **408** and **410**. Note that the connection and function of a switched capacitor voltage converter **402**, a voltage detector **404** and a voltage source **406** in FIG. 4 are substantially the same with those of FIG. 2, and thus, detailed descriptions are omitted for brevity.

According to this embodiment, when the negative magnitude of the input signals S_{in1} , S_{in2} , S_{in3} or S_{in4} is altered, the voltage generating apparatus **40** is capable of adjusting the output voltage **414** by an extra voltage **418** obtained from a current source controller **420**. Also, description has been given of a situation in which the output voltage **414** becomes unstable in the aforementioned embodiment accompanying FIG. 2. The ability for the output voltage **414** to be compensated by the switched capacitor voltage converter **402** and the voltage detector **404**, for example, can be expressed as below:

$$V_{out} = -V_{in} + V_c + (+/-V_{ei}),$$

where “ V_{out} ” represents the output voltage **414** derived from the switched capacitor voltage converter **402** shown in FIG. 4, “ V_{in} ” represents the first voltage **412** obtained from the voltage source **406**, “ V_c ” represents a predetermined voltage corresponding to a switching frequency **416** from the voltage detector **404**, and “ V_{ei} ” represents the extra voltage **418** provided for directly adjusting the output voltage **414**.

In this case, when the current source controller **420** controls the current flowing from the switched capacitor voltage converter **402**, the output voltage is accordingly increased. In addition, when the current source controller **420** controls the current flowing into the switched capacitor voltage converter **402**, the output voltage is then reduced. However, in other cases, the direction of the current flow may be reversed to adjust the output voltage **414** based on the design of the switched capacitor voltage converter **402** and the voltage source **406**.

It is also noted that the two amplifiers shown in FIGS. 2 and 4 for amplification are merely exemplary embodiments, and those skilled in the art may adjust the number of amplifiers to more than two amplifiers with the first voltage and the output voltage according to design necessity and components employed thereof while conforming with the principles of the invention.

FIG. 5 is a flowchart of a voltage generating method for driving at least one amplifier according to the invention. As mentioned above, the process starts with the generation of a first voltage provided to a positive voltage input terminal of

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the at least one amplifier (step s502), such as an operational amplifier, where the first voltage is a positive DC voltage.

Afterwards, an output voltage is obtained according to the first voltage and a predetermined voltage (step s504). Note that the output voltage is a negative DC voltage. Thereafter, the output voltage is then supplied to a negative voltage input terminal of the at least one amplifier (step s506). The at least one amplifier is then powered by an upper supply rail of the first voltage and a lower supply rail of the output voltage. In this embodiment, the first voltage and the output voltage are supplied to the at least one amplifier for audio signal amplification.

Finally, according to the output voltage, a switching frequency corresponding to the predetermined voltage is determined to adjust the output voltage (step s508). As described above, the output voltage is increased when the switching frequency is decreased. Further, the output voltage is decreased when the switching frequency is increased. That is, the predetermined voltage is inversely proportional to the switching frequency from the aforementioned description. Therefore, the voltage level of the output voltage can be compensated for and held constant by the predetermined voltage according to the switching frequency. It is more preferable to directly adjust the output voltage by an extra voltage. In one embodiment, the extra voltage is supplied from a current source controller. By utilizing the extra voltage, it is possible to carry out an adjustment of the output voltage when the negative magnitude of input signals of the at least one amplifier is changed.

While the invention has been described by way of example and in terms of preferred embodiment, it is to be understood that the invention is not limited thereto. To the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A voltage generating apparatus for driving at least one amplifier comprising:

a voltage source for providing a first voltage, wherein the first voltage is a positive DC voltage outputted to a positive voltage input terminal of the at least one amplifier;

a switched capacitor voltage converter coupled to the voltage source for outputting an output voltage to a negative voltage input terminal of the at least one amplifier according to the first voltage and a predetermined voltage, wherein the output voltage is a negative DC voltage; and

a voltage detector coupled to the switched capacitor voltage converter for determining a switching frequency corresponding to the predetermined voltage according to the output voltage,

wherein the switched capacitor voltage converter increases the output voltage when the switching frequency is decreased and decreases the output voltage when the switching frequency is increased.

2. The voltage generating apparatus as claimed in claim 1, wherein the first voltage and the output voltage are supplied to the at least one amplifier for audio signal amplification.

3. The voltage generating apparatus as claimed in claim 1, wherein the predetermined voltage is inversely proportional to the switching frequency.

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4. The voltage generating apparatus as claimed in claim 3, wherein the output voltage is determined by the following formula:

$$V_{out} = -V_{in} + V_c,$$

wherein V_{out} is the output voltage, V_{in} is the first voltage and V_c is the predetermined voltage.

5. The voltage generating apparatus as claimed in claim 1, wherein the voltage generating apparatus further comprises a current source controller coupled to the switched capacitor voltage converter for supplying an extra voltage to directly adjust the output voltage.

6. The voltage generating apparatus as claimed in claim 5, wherein the output voltage is set as a function of the first voltage, the predetermined voltage and the extra voltage, according to the following formula:

$$V_{out} = -V_{in} + V_c + (+/-V_{et}),$$

wherein V_{out} is the output voltage, V_{in} is the first voltage, V_c is the predetermined voltage, and V_{et} is the extra voltage.

7. The voltage generating apparatus as claimed in claim 1, wherein the at least one amplifier is an operational amplifier.

8. A voltage generating method for driving at least one amplifier comprising:

providing a first voltage to a positive voltage input terminal of the at least one amplifier, wherein the first voltage is a positive DC voltage;

generating an output voltage according to the first voltage and a predetermined voltage, wherein the output voltage is a negative DC voltage;

supplying the output voltage to a negative voltage input terminal of the at least one amplifier; and

determining a switching frequency corresponding to the predetermined voltage according to the output voltage, wherein the output voltage is increased when the switching frequency is decreased and is decreased when the switching frequency is increased.

9. The voltage generating method as claimed in claim 8, wherein the first voltage and the output voltage are supplied to the at least one amplifier for audio signal amplification.

10. The voltage generating method as claimed in claim 8, wherein the predetermined voltage is inversely proportional to the switching frequency.

11. The voltage generating method as claimed in claim 10, wherein the output voltage is determined by the following formula:

$$V_{out} = -V_{in} + V_c,$$

wherein V_{out} is the output voltage, V_{in} is the first voltage and V_c is the predetermined voltage.

12. The voltage generating method as claimed in claim 8, further comprising:

supplying an extra voltage to directly adjust the output voltage.

13. The voltage generating method as claimed in claim 12, wherein the output voltage is set as a function of the first voltage, the predetermined voltage and the extra voltage, according to the following formula:

$$V_{out} = -V_{in} + V_c + (+/-V_{et}),$$

wherein V_{out} is the output voltage, V_{in} is the first voltage, V_c is the predetermined voltage, and V_{et} is the extra voltage.

14. The voltage generating method as claimed in claim 8, wherein the at least one amplifier is an operational amplifier.

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